I. C. 6408

FEBRUARY, 1931

DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
SCOTT TURNER, DIRECTOR

INFORMATION CIRCULAR

# MILLING METHODS AND COSTS AT THE HOMESTAKE MINE, LEAD, S. DAK.

RECEIVED
MAR 11 1931
O. S. U. LIBRARY

BY

ALLAN J. CLARK

I. C. 6408
February, 1931

INFORMATION CIRCULAR

DEPARTMENT OF COMMERCE - BUREAU OF MINES

# MILLING METHODS AND COSTS AT THE HOMESTAKE MINE, LEAD, S. DAK.[1]

By Allan J. Clark[2]

## INTRODUCTION

This paper, describing the milling practice of the Homestake Mining Co., is one of a series being prepared by the Bureau of Mines.

The author acknowledges the assistance of T. G. Chapman, one of the consulting engineers of the Bureau of Mines, in arranging this paper for publication.

## HISTORY

The operations of the Homestake Mining Co. have been frequently described in its history of more than 50 years. A paper such as this, which aims to describe the milling practice of to-day, must necessarily begin with reference to the numerous papers that have preceded it.

The geology of the deposit has recently been discussed by Wright,[3] Hosted,[4] A. B. Yates,[5] Connolly,[6] and Paige.[7]

---

[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6408."

[2] One of the consulting engineers, U. S. Bureau of Mines; metallurgist, Homestake Mining Co.

[3] Wright, L. B., The Relation of the Tertiary Thyolites to Mineralization in the Homestake Mine: Black Hills Eng., vol. 14, No. 3, May, 1926, pp. 163-166.

[4] Hosted, J. O., Geology of the Homestake Ore Bodies and the Lead Area of South Dakota: Eng. and Min. Jour.-Press, vol. 115, Nos. 18 and 19, May 5 and 12, 1923, pp. 783-799, 836-843.

[5] Yates, A. B., The Occurrence of Quartz in the Homestake Mine (Lead, South Dakota): Black Hills Engineer, vol. 14, No. 3, May, 1926, pp. 167-171.

[6] Connolly, J. P., The Tertiary Mineralization of the Northern Black Hills: South Dakota Sch. Mines Bull. 15, September, 1927.

[7] Paige, Sidney, The Geology of the Homestake Mine: Econ. Geol., vol. 18, pp. 205-237, 1922.

Mining methods of recent years have been described by Wayland and Ross.[8]

Milling has been described in an exhaustive paper by Clark and Sharwood,[9] to which the reader is referred for many details that will not be repeated in this report. Later papers by Clark[10] and Robie[11] are also noted here.

Up to 1921 the milling plant comprised six stamp mills, all very similar in type and totaling 1,000 stamps.

Three of these mills were located in Lead, on the southern end of the property. Their ore supply, unoxidized in character, was derived, in the mai from lower levels of the mine. The stamp mills were supplemented by a "regrinding plant" of six tube mills. Tailings were classified into sand and slime, the former being treated in the No. 1 sand plant at Lead, and the latter passing through 3½ miles of pipe line to the slime plant at Deadwood.

The three other stamp mills, totaling 360 stamps, served the norther end of the property. They received the major portion of the ore drawn from the open cut and from the upper levels of the mine. In general, the ore was more or less oxidized and was softer than that drawn from the lower levels. The tailings product from these mills was classified, the sand being treated at No. 2 sand plant and the slime conveyed through pipe-lines to the slime plant. A single plant served for treatment of all the slime produced, and wa located at the confluence of the watersheds of Whitewood and Deadwood Creeks.

The stamps of these mills weighed from 900 to 1,000 pounds each. Amalgamation was developed to the extent that as much as 48 linear feet of amalgam plates was laid below the batteries in addition to the "chuck plates" in the mortars.

About 1920 moving ground made it necessary to abandon several of the old mills. The South mill, which was built to replace these, embodies material departures from the former methods practiced; it has been in operation since 1922.

---

[8] Ross, A. J. M., and Wayland, R. G., Mining Methods at the Homestake: Am. Inst. Min. and Met. Engrs., vol. 72, 1925, pp. 424-445.

[9] Clark, A. J. and Sharwood, W. J., Metallurgy of the Homestake Ores: Bull. 98, Inst. Min. and Met., Nov., 1912.

[10] Clark, A. J., Notes on Homestake Metallurgy: Trans. Am. Inst. Min. and Met. Eng., vol. 52, 1915, pp. 3-22.

[11] Robie, E. H., Milling Practice at the Homestake Gold Mine: Eng. and Min. Jour., Oct. 9, 1926, pp. 564-568.

At about the same time mining methods were modified, resulting particularly in the mining of large tonnages of ore from the caved and abandoned workings in the upper levels of the mine; this resulted in radical changes in the ore mixture. This "draw-hole" ore constituted as much as half of the total tonnage treated for several years after 1922. The then existing cyanide plants were none too well adapted for treating this ore, and the tonnage was insufficient to warrant other than limited expenditures for new plant construction. For several years the treatment of this ore had been attended by frequent adjustments and irregular results, a condition that is now passing but to which reference will be made in the course of this paper.

At present, three stamp mills are operated.

The South mill, constructed in 1922, has 120 stamps, each of 1,570 pounds falling weight, and has a capacity of 1,900 to 2,200 tons of ore per day.

The Amicus mill, originally constructed in 1878 and remodeled in 1924, contains 240 stamps of 1,100 pounds weight and has a capacity ranging from 1,200 to 1,400 tons of ore per day.

The Pocahontas mill, built in 1878, has 160 stamps of 950 pounds weight and ranges in capacity between 600 and 700 tons of ore per day.

Water is obtained from Spearfish Creek and from various water rights in smaller creeks of the vicinity. This water contains 10 to 15 grains of calcium and magnesium bicarbonates per gallon, amounts that have considerable bearing on metallurgical methods, since the reaction of the dissolved bicarbonates in the mill water with lime has prevented the use of an alkaline milling circuit, from which favorable results might have been anticipated.

Power is generated at the company's two hydroelectric developments on Spearfish Creek, which furnish about 35,000,000 kw.h. per annum. A central steam plant at Lead, fired with coal from the company's Wyoming mine, supplies the balance of the power requirements.

## ORE TREATED

Reference to the paper of Ross and Wayland, already cited, furnishes the following description of the ore:

> "The orebodies are found in a bed of altered dolomitic limestone occurring in a series of rocks believed to be of Archean age, belonging to the Keewatin series. The Keewatin series is made up essentially of quartz, mica schists, garnet schists, quartzites and slates. Ore is found generally in the altered dolomite, rarely in green schists. Where ore bearing, the altered limestone bed consists of cummingtonite and chlorite, with pyrite, arseno-pyrite and pyrrhotite.

> "The ore is hard and tough.....Ore from stopes breaks in large pieces, requiring much block-holing before loading.....Water has but little effect on clean ore, but makes a sticky mess of the draw-hole rock on account of the consistency of some of the waste."

W. J. Sharwood[12] gives the following typical analysis of Homestake ore:

| | Per cent |
|---|---|
| $SiO_2$ .................. | 54.0 |
| $Al_2O_3$ .................. | 7.7 |
| $Fe_2O_3$ and FeO ......... | 17.7 |
| FeS and $FeS_2$ ......... | 4.8 |
| MgO .................... | 4.1 |
| CaO .................... | 2.0 |
| $Na_2O$ .................. | .5 |
| $K_2O$ .................... | 1.2 |
| $H_2O$ (under 130° C.) ... | .2 |
| $H_2O$ (over 130° C.) and $CO_2$ ............ | 7.8 |

The average grade of the ore is about $5.00 per ton. Draw-hole rock, from the crushed zone of the old workings, is much lower than average grade on account of dilution with waste. On the other hand, more selective mining from the stopes is giving a higher average grade from this class of ore, as compared with earlier days.

About 75 per cent of the gold content can be amalgamated in laboratory tests. The usual recovery of gold by plant amalgamation runs from 60 to 65 per cent. Some of the gold is fairly coarse, but the greater part is finely disseminated through the ore.

From the metallurgical standpoint the most interesting fact is the occurrence of a considerable quantity of iron in the ferrous state. This ferrous iron enters into the composition of most of the gangue minerals. The cummingtonite, the chlorite, and the dolomitic limestone each contain as much as 30 per cent of ferrous oxide. In cyanide treatment slow withdrawal of oxygen from solutions, owing to the presence of these minerals, has determined the methods followed at Homestake plants.

---

[12] Sharwood, W. J., Analyses of Rocks from Homestake Mine: Econ. Geol., vol. 6, No. 8, Dec., 1911.

## PRESENT METHODS OF MILLING

In this paper, the description of present milling methods for several of the older units is omitted, and the description is thereby confined to the following more representative plants:

The South stamp mill, etected in 1922, treats 60 per cent of the total tonnage milled.

Cyanide sand plant No. 1, erected in 1901, treats 80 per cent of the sand fraction of the mill tailings.

The slime plant, erected in 1906, treats the total slime product of the mill tailings.

### Breaking and Coarse Crushing

There are three underground crushing stations, located below the 800-foot, 1400-foot and 2200-foot levels. Ore from the levels above the respective stations is trammed to a line of transfer raises, through which it is dropped upon grizzlies ahead of the crushers.

The grizzlies are made of 12 bars of 3½-inch material 6 feet long and spaced for 6-inch openings. The oversize of the grizzlies, amounting to approximately 70 per cent of the total product, is fed to the crushers by Allis-Chalmers apron feeders which are driven by belt from the motor operating the crusher. Traylor Bull Dog jaw-type crushers are used; these have 36 by 48 inch feed openings and are set to crush to 3½-inch size. The crushers are driven by 125-hp. motors and have a capacity of 250 tons per hour. The crusher discharge product and the grizzly under-size product pass to ore-loading pockets and thence by hoist to the crushing plant at Ellison shaft landing.

At this plant the ore is dumped from skips onto a deflecting platform, whence it is fed to a grizzly having 3-inch openings. This grizzly is made of cast-iron bars set into cast-iron supports on I-beams. The grizzly bars are 6 inches deep, 1½ inches thick at the top, and 1 inch thick at the bottom. The oversize of the grizzly is fed by two Stephens-Adamson apron feeders to four No. 6 B Allis-Chalmers gyratory crushers set at 3 inches. The discharge of these crushers falls upon a 36-inch belt equipped with a magnetic pulley and passes to a trommel with 3-inch openings. The trommel undersize product falls on a shuttle conveyor, where it is joined by the oversize product of the trommel after the latter has passed through two No. 6 B Allis-Chalmers crushers set at 2½ inches. The shuttle conveyor distributes the ore in the tramway storage bin, whence it is drawn into cars of 4 tons capacity and hauled to the mills. Gyratory crushers are used. The first set of crushers is belt driven by 25-hp. motors and the second set by 35-hp. motors.

In addition to the underground crushing stations and the surface plant at the main shaft another crushing station is located at the B and M hoist which crushes all ore from this shaft. The ore is broken to pass 12-inch openings in grizzlies before being hoisted. The ore from the skips goes to a bin in the headframe and thence to two No. 8 Allis-Chalmers gyratory crushers set at 4½ inches and driven by 70-hp. motors. The crushed product of these gyratories is fed to four No. 6 gyratory crushers set at 1½ inches and driven by 35-hp. motors. The crushed product is conveyed to tramway bins. There are no screens, grizzlies, or trommels in this plant.

## South Stamp Mill

### Stamps

Ore from the coarse crushers is delivered to the mill bin, of 7,200 tons capacity, in cars of 4-ton capacity, trains of 30 cars being hauled by compressed-air locomotives. The bin discharges ore through suspended Challenge-type feeders to the stamps.

Figure 1 gives the flow sheet of the South mill coarse-grinding department.

The retention of stamps in the flow sheet was determined primarily by the hardness of the rock and its tendency to break into large pieces. Crushers require very frequent adjustment, and even with this frequent adjustment the average crusher product is much too coarse for ball-mill feed. There are no available cost data to indicate that rolls would be more economical.

The stamp, however, is now used merely as a secondary crushing machine, preparing the ore for the rod mills which serve as primary grinders. The cost sheet, it is believed, justifies retention of these stamps.

The stamps, 120 in number, are arranged back to back on either side of the bin and parallel thereto. They are grouped in the conventional manner--five stamps to a mortar and two batteries set close together with a center post common to both. The cam shafts, however, carry but five cams, and each shaft is separately driven by a 25-hp. back-geared induction motor, operating at 600 r. p. m.

Mortar blocks are of concrete, one block serving 10 stamps. The falling weight of the newly assembled stamp is about 1,570 pounds. Table 1 gives the distribution of the weight of a stamp and the details of other battery parts.

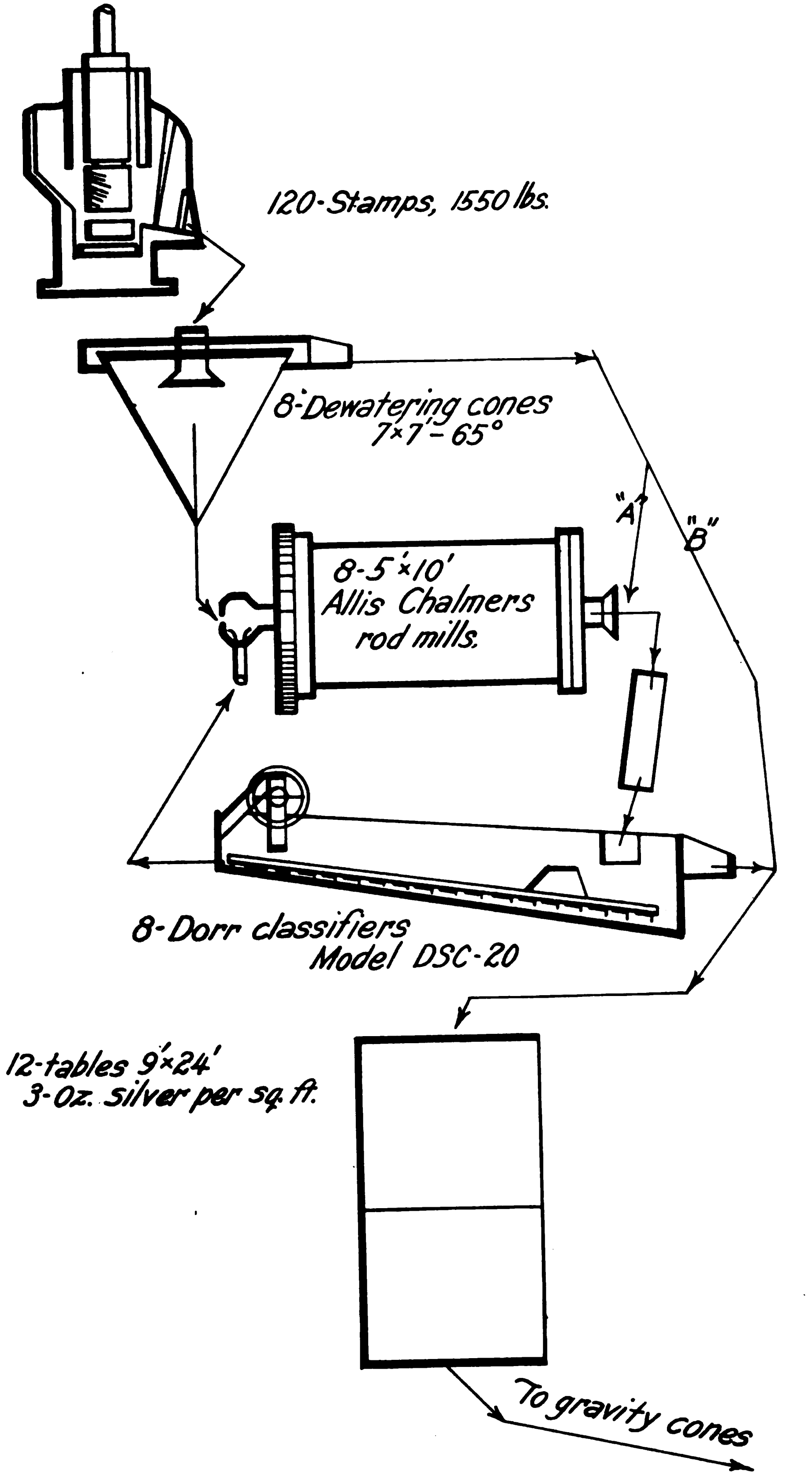

Figure 1.- South mill flow sheet, coarse grinding, 1927

Table 1.- Details of South mill battery parts

| Stamp part | Weight, pounds | Size | Life | Per cent of scrap | Material |
|---|---|---|---|---|---|
| Die ...... | 165 | 9¼ inch diameter by 8 inches | 62 days | 43 | White cast iron. |
| Shoe ..... | 250 | 9¼ inch diameter by 12 inches | 101 days | 21 | Manganese steel. |
| Boss head. | 520 | 9½ inch diameter by 31 inches | | | Chrome steel. |
| Stem ..... | 616 | 4-inch diamter by 14 feet 6 inches | | | Mild steel--0.03 per cent carbon. |
| Tappet ... | 188 | 9½ inch diameter by 17 inches (3 key) | | | Chrome steel. |
| Cam ...... | 260 | 32¾ inch horns, 13½ inch hub, 5½ inch face | | | Do. |
| Cam shaft.. | 895 | 6½ inch diameter by 8 feet 10 inches | 24 months | | Iron. |
| Mortar.... | 7,000 | | | | Cast iron. |
| Mortar liners--pocket.. | 45½ | 33-3/8 by 10¾ by ½ inches | 22 months | | Manganese steel |
| Mortar liners--back ... | 73 | 28-1/8 by 10¼ by 1 inches | 5 months | | Do. |
| Mortar screen.. | | 56 by 9 inches | 45 days | | Steel wire. |

A system of tipples and sumps is provided in the circuit that transports the stamp product to the dewatering cones. These were designed to secure flexibility in the mill and to permit the delivery of pulp from a battery to any one of two or three of the cones, and were particularly valuable in the earlier years of the plant. With standardization of practice continuous operation of all machines is the rule, and control of such variations as are introduced into practice by size and hardness of stamp feed or degree of fineness sought in rod mill grinding is now more readily effected by the use of suitable battery screens

Battery screens are frequently interchanged, and in this manner stamp duty is held to 15 tons per day or raised to 18 or more tons per day. The following table gives details of mill screens.

| Mill designation | Mesh and wire | Size of aperture, inch |
|---|---|---|
| No. 19 | Ludlow-Saylor, No. 19, Rek-Tang | 0.395 by 0.53 |
| 2½ mesh | 2½ mesh, No. 12 wire | .295 |
| 5/8 mesh | ¾ mesh, No. 8 wire | .588 |
| 11/16 mesh | 7/8 mesh, No. 8 wire | .713 |
| 7/8 mesh | 1 mesh, No. 8 wire | .838 |

## Primary grinding

The rod-mill section consists of eight units, each unit comprising one 7 by 7 foot dewatering cone, one 5 by 10 foot Allis-Chalmers rod mill direct-driven at the rate of 20.3 r. p. m. with a single reduction through herringbone gears by a 100-hp. motor, and one 4 foot 3 inch by 22 foot 6 inch Dorr classifier operating in closed circuit with the rod mill; and, in addition to the machines noted, certain amalgamating equipment.

Approximately 30 per cent of the solids in the stamp discharge product overflows the dewatering cones. This fraction is sufficiently fine for cyanidation and by-passes the rod mills. A portion of this overflow, however, is diverted to the discharge end of the rod mill and added to the rod-mill discharge to secure proper dilution of pulp in the classifier. No ill effects have been noted from this practice; and as it conserves water and, what is more important, thickening equipment, it is to be preferred to the addition of new water at this point.

The discharge of the dewatering cones passes to the rod mills. The rod-mill ends are lined with Allis-Chalmers alloy steel, and the cylindrical shell is provided with wave-type hard-iron liners of local manufacture. Discharge-end liners last about 2 years, feed-end liners about 4 years, and shell liners about 7 months. Rods are purchased from Colorado Fuel & Iron Co. and from the Illinois Steel Co. They are 3 inches in diameter by 10 feet long, contain 0.85 to 1.00 per cent of carbon, and are hot-rolled and machine-straightened. The initial rod load is about 23,500 pounds. The capacity of rod mills and rod consumption vary with the hardness and size of ore feed and also, of course, with the degree of fineness of grinding desired. A range in rod-mill capacity of 190 to 260 tons per day has been noted during the history of the plant.

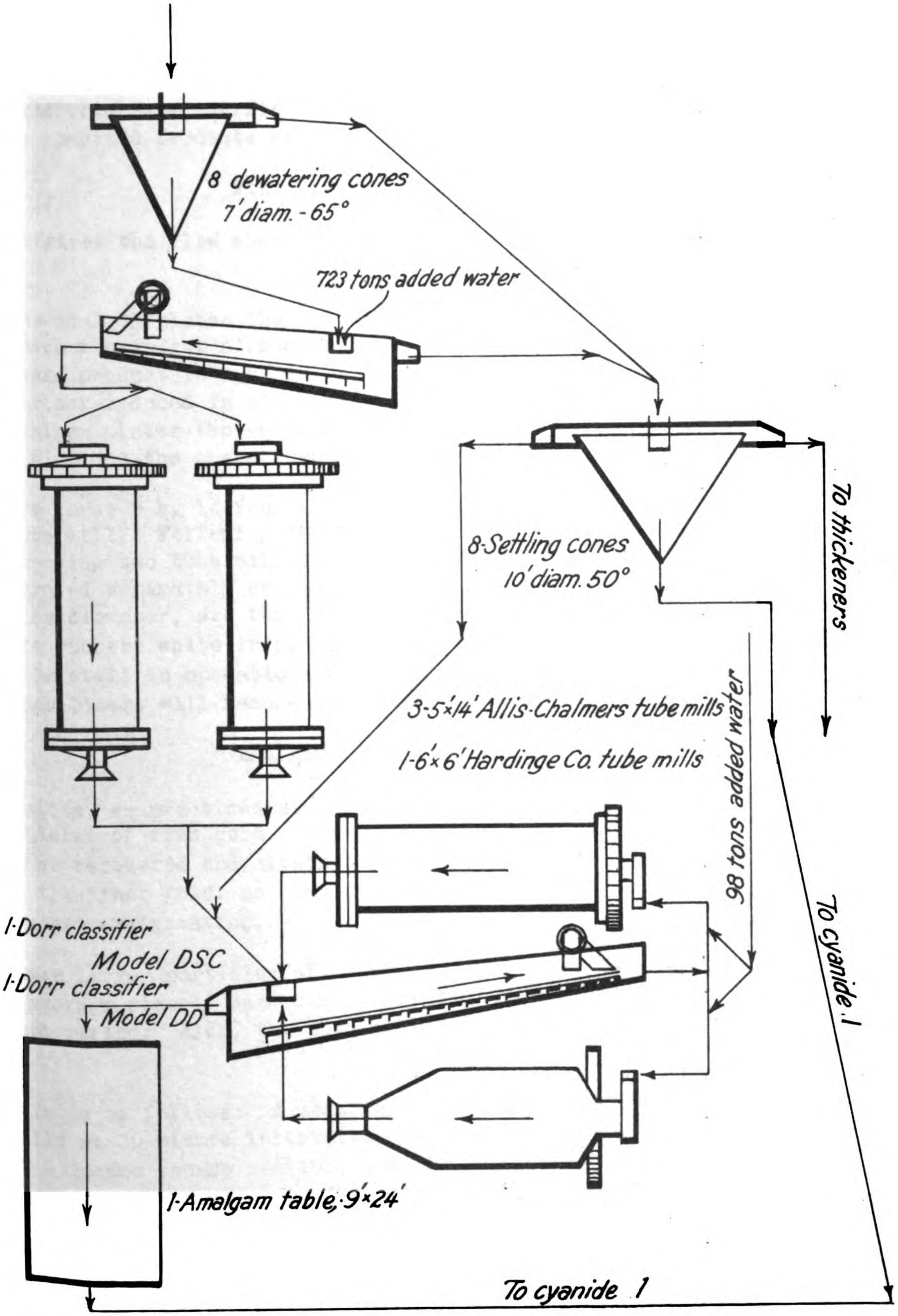

Figure 2:- South mill flow sheet, fine grinding, 1927

Dorr classifiers are set at $2\frac{3}{4}$ inches to 1 foot gradient, and the rakes operate at 34 strokes per minute. The classifier overflow goes to a screened sump into which the overflow from the dewatering cones also discharges, and the combined products pass thence to a set of amalgam plates.

## Fine Grinding

Figure 2 gives the flow sheet of the South mill fine-grinding department.

Below the amalgam plates the pulp enters a second series of dewatering cones, of which the spigot discharge passes to a Dorr classifier which discharges the sand product to tube mills. In the tube mills the coarser particles are further reduced in size, and after passage of the reground material over amalgam plates the separation of sand from slime, preparatory to cyanidation, finishes the operations within the mill.

There are three 5 by 14 foot Allis-Chalmers tube mills and one 6 by 6 foot Hardinge tube mill. Following the tube mills are two Dorr classifiers, one classifier serving two tube mills. The arrangement is such that these mills can be operated separately or in tandem, as desired. French pebbles, about $2\frac{1}{2}$ inches in diameter, are the grinding media. Mill linings are of Goodrich Linerite rubber, white iron, or Belgian silex. The first rubber liner installed is still in operation after 4 years of service. It is expected that rubber liners will become standard as renewals are made.

## Amalgamation

Amalgamation, as practiced at the South mill, is planned to recover the coarser particles of free gold. Although some of the finer free gold particles are also recovered and although some plate surface is provided as an aid in securing the finer gold, no concern is felt if particles finer than 100-mesh size escape amalgamation.

When these larger particles of gold are removed from the pulp a rather coarser average size of sand can be treated by cyanidation and in a briefer treatment period. Also, the gold so recovered is won at a somewhat lower cost.

Procedure is as follows: A measured quantity of quicksilver is fed into the rod mills at 30-minute intervals. These mills discharge into shallow sumps of about 18 inches square section, and the pulp is diluted in these sumps by the addition of a portion of the cone overflow that by-passed the rod mill. This diluting stream enters the side of the sump at right angles to the axis of the rod mill, thus setting up an eddying action in the sump and providing a 90° sector wherein the flow is retarded; and conditions are established which favor the settling out of the larger particles of amalgam. The sumps are cleaned out once per week.

From the sump the pulp overflows to a launder through which it travels to the classifier. Upon the bottom of this launder rests a silvered copper plate, 12 inches wide by 7 feet long. Amalgam builds up rapidly on this plate, which is heavily coated in about 4 hours, when it is replaced with a freshly cleaned and dressed strip.

The classifier overflow passes to the main series of amalgam plates. There are 12 sets of these, each 9 feet wide and 24 feet long. They are built up of copper plates 12 feet long and $4\frac{1}{2}$ feet wide by 1/8 inch thick, plated with 3 ounces of silver per square foot. The plates are mounted on wooden tables, which are supported by jacks so that the grade may be adjusted as desired. Normally, the slope amounts to 1 inch per foot. The 24-foot length is broken by a short drop from the upper 12 feet of plate to the lower half. No trap is provided at the foot of the amalgam tables, but the pulp flows from the tables to a deep sump which serves as a trap and which is cleaned out at long intervals.

In addition to the amalgam plates described a single 9 by 24 foot amalgam plate is placed below the tube mills in the fine-grinding section to recover gold released by regrinding.

Plates are dressed and cleaned once a day. Amalgam is softened by the addition of quicksilver and swept from the plate with house brooms. In cleaning up, quicksilver is added to the amalgam, which is then ground in Wedgewood mortars and squeezed in a power machine of home manufacture. Skimmings are ground in a small iron barrel and then cleaned in the usual way. The richer pyritic product from grinding is used as a blast-furnace flux in refining operations.

Quicksilver is distilled from the amalgam in gas-fired retorts; the crude bullion, amounting to approximately 45 per cent, by weight, of the amalgam, is then melted in graphite pots, in coke-fired wind furnaces.

Table 2 gives gold assays, pulp consistencies, and screen sizes of South mill intermediate and final products.

Table 3 summarizes costs of amalgamating, and Table 4 gives unit costs of amalgamating.

Table 2. – Assays, pulp consistencies, and screen sizes of South mill intermediate and final products

| Product | Assay dollars per ton | Weight, tons |  | Ratio, water to solids | Screen sizes, per cent |  |  |  |  |  |  |  | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  | On, mesh |  |  |  |  |  |  | Thru 200 mesh |  |
|  |  | Water | Solids |  | 10 | 30 | 50 | 80 | 100 | 150 | 200 |  |  |
| Stamp discharge ............. | 4.90 | 10,670 | 1,940 | 5.5 | 34 | 25 | 9 | 4 | 1 | 4 | 4 | 19 |  |
| Coarse grinding section |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Dewatering-cone discharge.. | 5.60 | 530 | 1,510 | .35 | 43 | 32 | 12 | 5 | 1 | 3 | 1 | 3 | This is the new feed to the rod mills. |
| Dewatering-cone overflow "A" | 2.44 | 4,720 | 200 | 23.6 |  |  |  | 2 | 1 | 8 | 13 | 76 | To rod-mill discharge. |
| Dewatering-cone overflow "B" |  |  | 230 | 23.6 |  |  |  | 2 | 1 | 8 | 13 | 76 | To plate tables. |
| Rod-mill classifier overflow.. | 2.22 | 5,250 | 1,710 | 3.1 |  |  | 11 | 13 | 5 | 11 | 11 | 49 |  |
| Plate heads .................. | 2.27 | 10,670 | 1,940 | 5.5 |  |  | 10 | 11 | 4 | 10 | 10 | 55 |  |
| Plate tailings ............... | 1.87 | 10,670 | 1,940 | 5.5 |  |  | 10 | 11 | 4 | 10 | 10 | 55 | Feed to gravity cones of fine-grinding section. |
| Fine-grinding section |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Gravity-cone discharge ..... | 2.76 | 149 | 373 | .4 |  | 2 | 32 | 30 | 9 | 9 | 6 | 13 | To primary tube-mill classifier. |
| Gravity-cone overflow ...... | 1.66 | 10,526 | 1,567 | 6.7 |  |  | 4 | 7 | 3 | 10 | 11 | 65 | To settling cones. |
| Primary tube-mill classifier overflow ............... | 2.20 | 748 | 128 | 6.0 |  |  | 6 | 24 | 8 | 13 | 9 | 40 | Do. |
| Primary tube-mill feed ..... | 3.06 | 85 | 245 | .35 |  | 3 | 44 | 32 | 9 | 7 | 2 | 2 |  |
| Primary tube-mill discharge. | 3.06 | 85 | 245 | .35 |  |  | 18 | 31 | 9 | 14 | 7 | 21 | To No. 2 Dorr classifier. |
| Secondary tube-mill classifier feed ...................... | 2.77 | 85 | 245 | .35 |  |  | 18 | 31 | 9 | 14 | 7 | 21 |  |
| Secondary classifier overflow. | 2.77 | 885 | 298 | 3.0 |  |  | 5 | 15 | 14 | 16 | 10 | 40 |  |
| Tube-mill section-plate tailings ...................... | 2.51 | 1,081 | 298 | 3.6 |  |  | 5 | 15 | 14 | 16 | 10 | 40 | To cyanide plant No. 1. |
| Settling-cone feed .......... | 1.70 | 11,274 | 1,695 | 6.7 |  |  | 5 | 8 | 3 | 10 | 11 | 63 |  |
| Settling-cone discharge ...... | 1.80 | 4,625 | 1,250 | 3.7 |  |  | 6 | 11 | 4 | 14 | 15 | 50 | Do. |
| Settling-cone overflow "A" ... | 1.42 | 5,882 | 392 | 15.0 |  |  |  |  |  |  | 0.5 | 99.5 | To thickeners. |
| Settling-cone overflow "B" ... | 1.42 |  | 53 |  |  |  |  |  |  |  | 0.5 | 99.5 | To tube mill discharges. |
| To cyanide plant No. 1 ....... | 1.94 | 3,706 | 1,548 | 3.7 |  |  | 6 | 12 | 6 | 14 | 14 | 48 | Mill sand tailings. |
| To Hill thickeners ........... | 1.42 | 5,882 | 392 | 15.0 |  |  |  |  |  |  | 0.5 | 99.5 | Mill slime tailings. |

Table 3. - Cost of amalgamation

| Amalgam from | Net doré, ounces | Net recovery | Net recovery per ton | Labor | Supplies | Total cost |
|---|---|---|---|---|---|---|
| Rod-mill circuit and plates ... | 92,876.90 | $1,592,331.55 | $2.2666 | $1,862.14 | $1,248.44 | $3,111.58 |
| Main plates ..... | 12,706.67 | 230,875.83 | 0.3286 | 2,212.18 | 2,097.22 | 4,309.40 |
| Tube-mill plates | 1,667.07 | 24,363.14 | 0.0347 | 112.38 | 167.60 | 279.98 |
| Total .......... | 107,250.64 | $1,847,570.52 | $2.6299 | $4,186.70 | $3,514.26 | $7,700.96 |

Table 4. - Unit costs of amalgamation

| | Per fine ounce of gold | Per dollar recovered | Per ton of ore milled |
|---|---|---|---|
| Rod-mill circuit and plates. | $0.0407 | $0.00195 | $0.00443 |
| Main plates ................ | .3874 | .01866 | .00613 |
| Tube-mill plates ........... | .2405 | .01149 | .00040 |
| All sources ................ | .0779 | .00417 | .01096 |
| Cost of retorting, melting, and shipping (up to delivery to express company) in addition to above .............. | .0467 | .00250 | .00657 |
| Total ...................... | $ .7932 | $ .03877 | $ .02849 |
| Quicksilver lost ........... | | .0296 troy ounce | .0778 troy ounce |

## Cyanidation

Before beginning a description of the methods employed in cyanidation it may be advisable to emphasize the supplying of oxygen, the underlying feature of this operation upon which all other steps depend.

The supplying of oxygen by forcing compressed air through the drained charge is rendered necessary by the presence of the many ferrous compounds already mentioned.

Laboratory tests of selected samples of ore have shown a consumption of oxygen per ton of ore equivalent to that contained in 134 cubic feet of free ai The highest consumption was shown by the nearly barren cummingtonite, but the property of consuming oxygen is shared by almost all the ore minerals.

The necessity for aeration demands that the classification be thorough. A sand charge must be evenly permeable throughout without soft or slimy pockets Aeration must precede the application of the cyanide solution to render harmless the compounds that would otherwise destroy cyanide. Application of the cyanide before aeration doubles the consumption of cyanide.

With these preliminary notes the description of the procedure at No. 1 sand plant, the larger and older of the two sand plants, which has been in operation since 1901, will be given.

## No. 1 Sand Plant

Separation of the sand from the slime, the first step in the process, is partly accomplished in the stamp mills, where the mill tailings go to a battery of gravity cones 10 feet in diameter with a 50° slope.

The overflows of these cones pass to thickeners and the discharge products to a second battery of cones. The discharge products of the secondary cones are further treated in hydraulic cones where water, admitted through an annular opening immediately above the discharge bushing, assists in washing the sand free from the last particles of slime.

Numbers, dimensions, and other pertinent data of the cones contributing to the No. 1 sand plant are given in the following table.

| Description | Receives feed from | Location | Number | Diameter, feet | Slope, degrees | Diameter of bushing, inches |
|---|---|---|---|---|---|---|
| No. 1 gravity cones | Amicus mill | Amicus mill | 8 | 10 | 50 | 1-1/2 |
| Do. | South mill | South mill | 8 | 10 | 50 | 1 to 1-1/8 |
| No. 2 gravity cones | Discharge of No. 1 cones | Cyanide sand No. 1 | 10 | 7½ | 50 | 21/32 |
| Hydraulic cones ... | Discharge of No. 2 cones | Cyanide sand No. 1 | 20 | 4 | 70 | 25/32 |

The overflows from these several batteries of cones are clarified and the slime is thickened in several groups of thickeners of various sizes and types. Some of these date from 1901, others are as recent as 1926. Simple gravity tanks, with hopper bottoms; Dorr thickeners, both single and tray types, in diameters from 18 feet to 54 feet, are included. The most satisfactory units are single 54-foot-diameter Dorr thickeners, with the discharges through bushings, similar to the cone bushings, readily adjustable.

Sand discharging from the hydraulic cones passes in tile-lined launders to the distributors, of which there are three, each serving a row of leaching vats by means of a carriage moving along an overhead track. Distributors are of the Butters-Mein type and present no unusual features.

The sand vats, 19 in number, are of redwood, bound with round hoops, of galvanized mild steel. They are 44 feet inside diameter and 10 feet 5 inches deep from top of staves to top of filter canvas. A charge of sand 118 inches deep contains 670 tons.

Filter bottoms consist of cocoanut matting, resting on a slatted wooden frame of pine strips, 2 by 4 inches, notched on the underside. Upon the matting is a sheet of 10-ounce canvas duck, which is secured by calking around the outside edge with a one-inch rope. Matting lasts 10 years or more, finally becoming so choked with lime that it must be replaced; canvas wears 18 months.

At the level of the filter cloth are four side gates for sluicing out residues. These are hinged and fastened by swing bolts and supplemented by a circular center-discharge gate, which operates by a threaded rod and hand wheel through a column projecting above the level of the staves. The top of this column supports the distributor.

Ongoing weak and strong solutions and water are conveyed in pipe lines which run above and between the lines of vats. Valves opposite each vat permit communication by a manifold to distributing pipes, which deliver solutions to four points on the charge.

Below the filter are valved openings communicating with the pipe systems which convey the several pregnant solutions to their several sumps. Effluent solutions are divided as follows:

1. "Strong" is solution which is brought to maximum strength in cyanide but from which the values are not precipitated before pumping to storage tanks used for ongoing solutions.

2. "Weak" is solution from which the values are precipitated but which is not strengthened in cyanide. After precipitation it is pumped to storage tanks containing ongoing solutions.

3. "Low" is solution that is wasted, after precipitation of the gold and silver, to preserve the balance of solutions.

4. "Waste", which is little more than displaced water, is run direct to the sewer.

The method of treatment aims to pass the solution through two charges of sand before precipitation, thus concentrating the dissolved gold and silver in a smaller amount of solution. This is accomplished by using barren or newly precipitated solution in the latter stages of treatment of one charge, then strengthening this effluent and using it again, without previous precipitation, in the early treatment stages of a subsequent charge.

Aeration of the sand charge is accomplished by introducing air below the filter bottom at a pressure slightly above that of the column of sand through which it must pass. Air is compressed in an Ingersoll-Sergeant steam compressor, converted to electric drive, and delivering 625 cubic feet of free air per minute, at 8 pounds pressure. This air is delivered to the vats

Digitized by Google Original from THE OHIO STATE UNIVERSITY

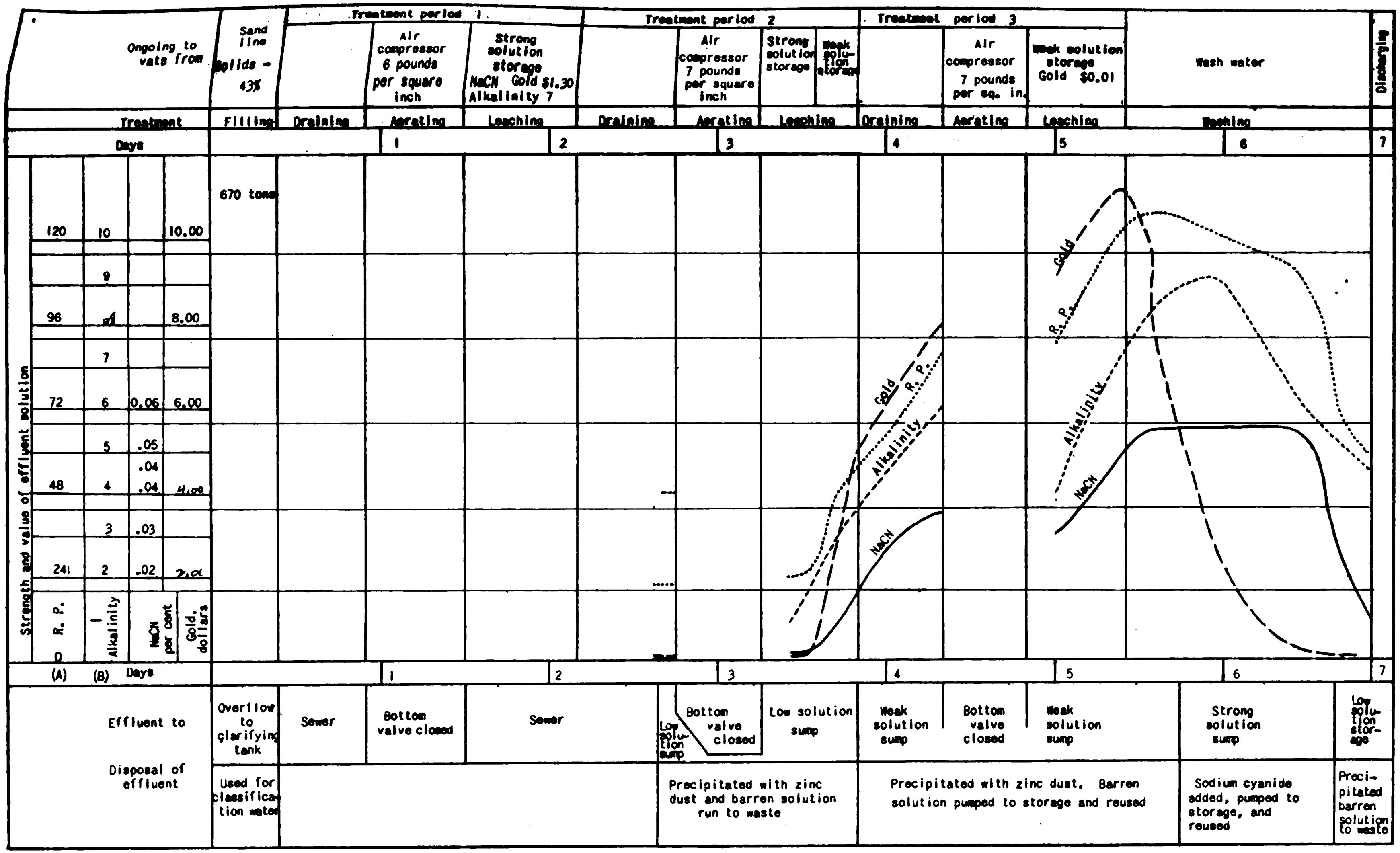

Figure 3.- Cycle of sand treatment in leaching vats, Homestake Mining Co., 1930 : A, Reducing power is expressed as the number of cubic centimeters of N/10 potassium permanganate consumed by 100 c. c. of the solution tested; B, alkalinity is expressed as the number of cubic centimeters of N/10 acid required to neutralize 100 c. c. of the solution tested, one unit corresponding to 0.0028 per cent of CaO

through a pipe which enters below the filter bottom. A gage installed on the operating floor permits the attendant to control the operation. For successful aeration the charge must be free from slime pockets, as previously stated; it must be thoroughly drained, and the air pressure must be carefully controlled.

Lime is crushed in a 1-stamp battery through a 7-mesh screen and fed to the pulp entering the distributor. An extremely low alkalinity is desired, but it is sought to maintain this evenly throughout treatment. It has been found that particles of lime passing this screen will just about last out the treatment period before being completely dissolved. Protective alkalinity of not more than 0.1 pound of CaO per ton is sufficient. A high alkalinity retards and even inhibits complete extraction.

The treatment cycle consists of three periods, each of which, in turn, is divided into three parts, covering draining, aerating, and leaching. The third period is followed by washing and discharging.

Discharging of tailings is accomplished by sluicing. A ton of sand can be discharged with about ¾ ton of water, but when time is available about twice this amount may be used, the water pressure in the latter case being but approximately 10 pounds.

The accompanying chart (fig. 3) shows all operations entering into treatment and a graph of the effluent solutions.

A typical sand charge, 118 inches deep, will leach at a rate of 1½ to 2 inches per hour, as measured by the fall in level of the supernatant solution. Such a charge will have a screen analysis about as follows:

| Tyler standard screens, mesh | Per cent |
|---|---|
| On 50 ........................ | 4 |
| Through 50 on 80 .......... | 15 |
| Through 80 " 100 .......... | 14 |
| Through 100 " 150 .......... | 17 |
| Through 150 " 200 .......... | 18 |
| Through 200 ................. | 32 |

Because of the denseness of newly mined, unoxidized ore and the more porous structure of the oxidized material and also because the tailings are of such a low tenor in gold it is difficult to make a definite statement as to the optimum size to which ore should be reduced. It may be stated that the sulphides yield their values at all sizes more readily than do the gangue minerals; that the coarser fractions of oxidized ore yield a larger proportion of their content than do the unoxidized particles of the same size; and that it is probably justifiable in practice to grind rather finer than grading analyses would seem to warrant.

## Slime Plant

In its essentials slime treatment follows the same procedure as sand treatment, in that oxygen is supplied to the charge, solutions are recirculated before precipitation and protective alkalinity is carried at an extremely low point.

Treatment is accomplished in Merrill filter presses of 90 frames, each frame measuring 6 feet by 4 feet by 4 inches at pressures of 25 to 30 pounds per square inch. There are 31 presses, each of which treats 24 tons of slime at a charge.

These presses are of the flush-plate and distance-frame pattern. Channels are internal, and sluicing is automatic, being accomplished by means of a 3-inch water pipe extending through a 6-inch passage which opens into each frame at the bottom center.

Where the pipe is midway between the two canvas-covered plates - in other words, at the bottom center of the 4-inch slime cake - a bushing, bored to 5/32-inch diameter, is tapped into the sluicing bar. Water at 70 pounds pressure is admitted to the sluicing bar, which is mechanically rotated backward and forward through an arc of about 200° until the slime is discharged through outlets which are provided at intervals in the bottom of the channel through which the sluicing bar passes.

Reference is made to the earlier paper by Clark and Sharwood, which has already been cited, for an exhaustive description of the construction and operation of these presses.

A double cloth covers the plates and serves as a filter medium. A light muslin twill is in contact with the corrugated surface of the plate, and above this is a No. 10 cotton duck, weighing about 1.6 ounces avoirdupois per square foot. This arrangement is preferred to a single cloth, as favoring circulation of solution and reducing the number of leaks due to imperfections of weave. As the cloth grows older leaks become more frequent, so that the slime escaping treatment from this cause, together with the cost of repairing and replacing torn cloths, offsets the cost of a new set. Hence, the varying cost of cloth determines the length of service. Two years is about an average life.

At the slime plant the treatment cycle is but approximately nine hours. Lime, added to control alkalinity, must be available within this time, and it must also counteract a greater initial acidity than is encountered in sand treatment. Accordingly, the lime is slaked in a small tank, mixed with water, and fed to the sludge containing about 35 per cent of solids entering the receiving tanks at the plant. The nature of the water supply, already mentioned, prevents what would otherwise be the logical step, namely, the addition of

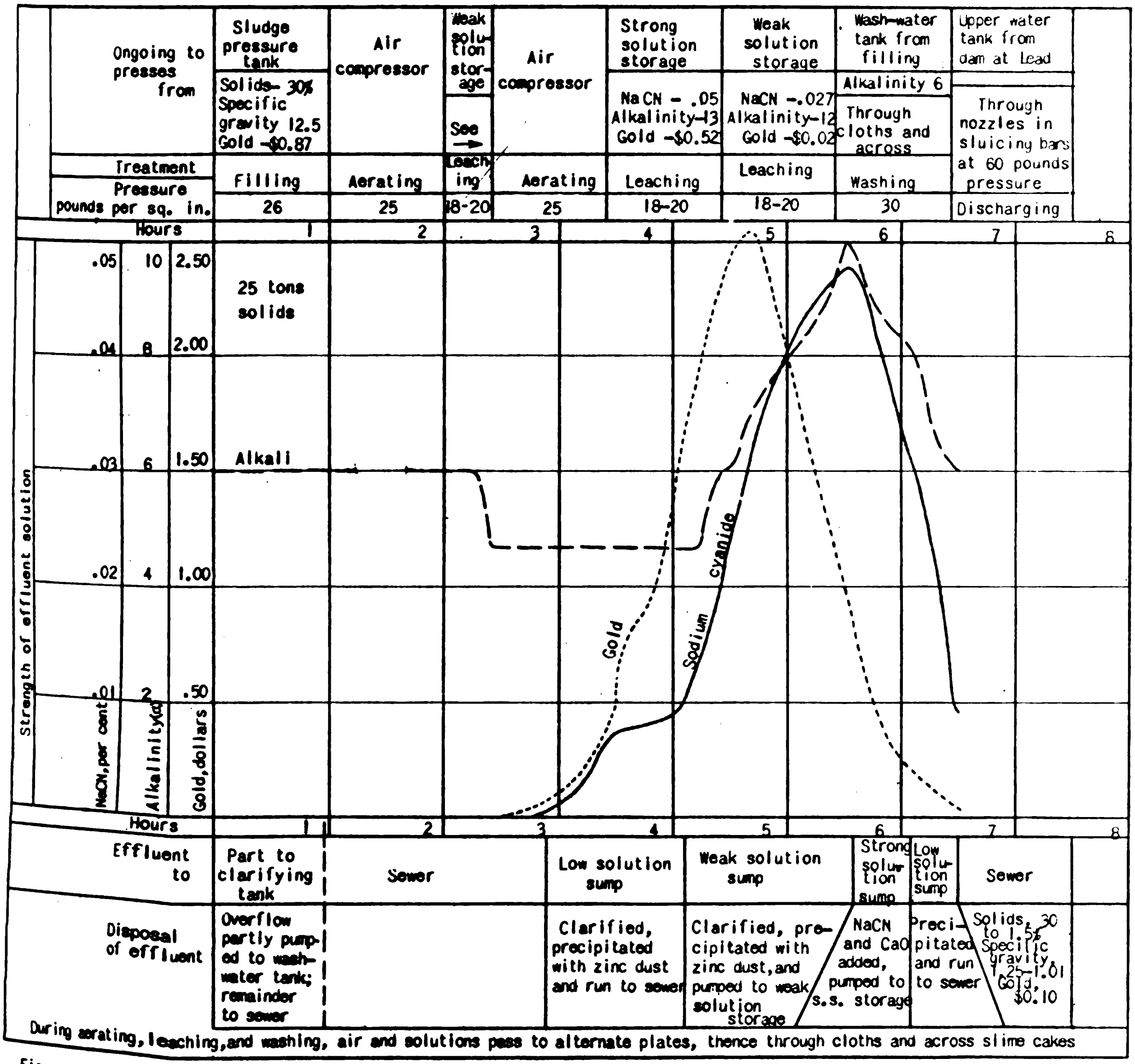

Figure 4.- Cycle of slime treatment in Merrill press, Homestake mine, 1911. Alkalinity is expressed as the number of cubic centimeters of N/10 acid required to neutralize 100 c. c. of the solution tested, one unit corresponding to 0.0028 per cent of CaO

lime at the intake of the transportation pipes 3 miles away. The reaction between the bicarbonate water and lime also operates to precipitate lime carbonate on press cloths and necessitates treating these with 0.7 per cent hydrochloric acid solution at intervals of about three weeks.

Permeability of the charge determines the length of treatment, as extraction depends more on the passage of a definite amount of solution than it does on the strength of that solution in cyanide. The working strength is dictated by the lowest effluent strength that can be carried with assurance that precipitation will be satisfactory.

Analyses of working solutions disclose nothing of interest other than the presence of considerable amounts of thiocyanates. At the sand plants the solutions will run from 0.10 to 0.20 per cent. As these are stable compounds they represent a definite loss of cyanide, but even with concentrations of double the strength noted above they have no adverse effect on extraction.

Sulphides are rarely present. When they do occur it is but for a few days at a time and never in large amounts. They are never noted except in slime-plant solutions resulting from treatment of "draw-hole" ore.

The slime presses were designed to treat the rather free-leaching slime from freshly mined ore which carried at least the average amount of cummingtonite. When fresh the needlelike crystals of this mineral keep the charge rather open and loosely packed; when decomposed it contributes the most undesirable clay with which the plant has to deal. Some such material, from the "draw-hole" territory, settles and leaches at but 7 per cent the rate of unoxidized slime.

In the earlier period of slime-plant operation a 4-inch cake was leached readily. With "draw-hole" material, 4 inches was an excessive thickness. Clean washing, satisfactory aeration, indeed, even proper filling and discharging of presses were at times almost impossible to accomplish. Moreover, interference by organic matter of various origins added to the difficulties of treating ore of this class. On this account, two treatment charts are presented. The first, Figure 4, shows slime treatment as practiced by the Homestake company in 1911 and the second, Figure 5, deals with treatment as practiced in 1930.

As with the sand-treatment chart, these present all the details of treatment, together with a graph of the effluent solutions.

## Precipitation and Refining

Precipitation of gold and silver in all cyanide plants of the Homestake company is by zinc dust, using the Merrill-Crowe process.

Sand-plant solutions need no clarification before precipitation treatment; slime-plant solutions are clarified, although during most of 1929 the "low" solution at that plant was precipitated without clarification, with resultant high consumption of zinc.

Standard equipment consists of Merrill precipitation presses, Homestake zinc feeders, Aldrich pumps for solution, and Gardner-Rix vacuum pumps.

At the sand plant there are two presses of 32 plates each, plates being triangular and 52 inches in size. The plates are covered with a double layer of cotton cloth, the variety used being known as "No. 1.30 Sateen". At a cleanup the layer in contact with precipitate is removed and burned, the ash being added to the precipitate. The back layer is moved forward, a new cloth being placed in contact with the frames. Washing of cloths and reuse for a second 2-cleanup period have been resorted to at times but are not warranted at the current prices of cotton goods. Paper has not been satisfactory as a substitute for cloth.

Solution, drawn from tanks through the vacuum equipment, flows to the suction of a 7 by 72 inch Aldrich triplex pump, driven through gears by a 2-speed, General Electric motor, Type I, 440-volt, 10 hp., 900 r. p. m. at high speed. Zinc dust, to which a small quantity of "Celite" is added, is fed continuously at this point. A drip of strong lead nitrate solution is also fed. The zinc dust is added from a Homestake feeder of the belt type, driven through a train of gears by an electric motor. Belt travel of the feeder is at rate of 30 inches per hour. Pumping is at high speed until the maximum pressure of 35 pounds is reached; thereafter it is at low speed.

At the sand plant, "weak" and "low" solutions are pumped alternately through the same presses, the latter being turned to waste after precipitation of the gold and silver. This system makes for economy in zinc and is looked upon as the ideal method, but it is not practicable to follow the procedure at the slime plant, where much larger tonnages of solutions are precipitated, necessitating continuous pumping in each of the two precipitation systems.

Barren solutions are tested hourly by the Dowsett method, and zinc feed is adjusted as indicated. The Dowsett method is a colorimetric method, and the presence of as little as 0.02 dwt. of gold per ton of solution is very plainly shown. Control samples of both pregnant and barren solutions are assayed daily.

Precipitate is removed from presses once a month, except at No. 1 sand plant, where byweekly cleanups are made. In cleaning up, the press is blown for two hours, with air at 10 pounds pressure. The press is then dumped, the cloths scraped and both precipitate and cloths boxed and moved to the refinery at Lead.

Acid-treatment equipment is available and is sometimes used when much zinc or sediment is present. This, however, is not often the case.

Precipitate is partly dried, then mixed with a flux consisting of litharge, borax, and coke, and briquetted in an air-actuated press at a pressure of about 3,000 pounds. The bricks are 5 inches in diameter by 4 inches high and weigh approximately 7 pounds.

These are dried, then charged upon a bath of lead to an oil-fired furnace, in which the operations of fusion and cupellation are performed. The furnace is of the type known as an English cupelling furnace, with a test 4 feet 1 inch by 3 feet 6 inches and about 7 inches deep. The test frame is of cast iron, and is filled with a mixture of 75 per cent cement and 25 per cent crushed limestone ranging between 10-mesh and 30-mesh in size. Small water jackets protect the sides of this test, which is used for but a single run.

The procedure is to charge briquets until the test is full, then to draw off slag, with some matte and lead accompanying it, into slag pots, repeating the operation until all the briquets have been charged and fused. Such lead as has been drawn off with slag is made ready to return to the test. A blast of air, at low pressure, is blown across the surface of the lead bath, and litharge is drawn off continuously from the front until at the end of the process a doré bar of about 960 fineness in gold and silver remains in the test. This is withdrawn and melted in a graphite pot to bars of suitable size.

Slags, mattes, sweepings, test bottoms, and all the miscellaneous accumulations of refinery and mills are smelted monthly with lead in a small blast furnace. Some of the lead so recovered is added to the cupelling furnace before briquets are charged, as fusion of the briquets is speeded up by thus charging them on a bath of molten metal. The remaining lead is added from time to time during cupellation.

## Recovery

The total recovery of gold is somewhat over 93 per cent, rarely reaching 94 per cent. The recovery and loss of gold are distributed about as follows:

| | Per cent | |
|---|---|---|
| Recovery by amalgamation .................. | 62.8 | |
| Recovery by cyanide treatment of sand ..... | 20.6 | |
| Recovery by cyanide treatment of slime .... | 9.6 | |
| Total recovery ......................... | | 93.0 |
| Loss in sand tailings ..................... | 4.6 | |
| Loss in slime tailings .................... | 1.8 | |
| Loss in slime wasted ...................... | .6 | |
| Total loss ............................. | | 7.0 |
| Total accounted for .................... | | 100.0 |

## Metallurgical data

Table 5 gives metallurgical data of the South mill, cyanide sand plant No. 1, and the slime plant, for the year 1929.

Table 5. - Metallurgical data

| | |
|---|---|
| **Stamps** | |
| Stamp duty, tons | 16.33 |
| Ore stamped per man-hour, tons | 26.1 |
| Kw.-hours per ton stamped | 3.892 |
| Average life of shoes, days | 101 |
| Average life of dies, days | 62 |
| Iron consumption of shoes, pounds per ton | .157 |
| Iron consumption of dies, pounds per ton | .166 |
| Iron consumption, shoes and dies, pounds per ton | .323 |
| **Rod mills** | |
| Duty per mill, tons per 24 hours | 199 |
| Ore ground per man-hour, tons | 25.8 |
| kw.-h. per ton ground | 6.805 |
| Rod consumption, pounds per ton | 1.30 |
| Shell-liner consumption, pounds per ton | .346 |
| End-liner consumption, pounds per ton | .018 |
| Total liner consumption, pounds per ton | .364 |
| **No. 1 cyanide sand plant** | |
| Lime per ton of sand treated, pounds | 2.74 |
| Aero cyanide per ton, pounds 49 per cent NaCN | .3885 |
| Zinc per ton, pounds | .0303 |
| Gold precipitated per pound of zinc, dollars | 64.94 |
| Solutions per ton of sand treated, tons | |
| Strong solution | .235 |
| Weak solution | .224 |
| Low solution | .145 |
| Total solution | .604 |
| Power per ton of sand treated, kw.-hours | 1.033 |
| Labor, tons per man-hour | 9.5 |
| **Slime cyanide plant** | |
| Lime per ton of slime treated, pounds | 4.178 |
| Aero cyanide per ton, pounds 49 per cent NaCN | .533 |
| Zinc per ton, pounds | .086 |
| Gold precipitated, per pound of zinc, dollars | 13.51 |
| Acid used per ton of slime treated, pounds | .44 |
| Solutions per ton of slime treated, tons | |
| Strong solution | .31 |
| Weak solution | .64 |
| Low solution | .33 |
| Total solution | 1.28 |
| Power per ton of slime treated, kw.h. | 1.77 |
| Labor, tons per man-hour | 7.0 |

## Costs

The total milling cost for the year 1929, including all plants of the Homestake company, amounted to $0.503 per ton of ore milled. This cost was divided as follows:

| | Per ton |
|---|---|
| Cost of crushing in mine and at hoists. | $0.038 |
| Cost of milling ...................... | .276 |
| Cost of cyaniding ..................... | .189 |
| Total ............................... | $ .503 |

Table 6 summarizes tramming and coarse-crushing costs for 1929.

Table 7 summarizes grinding and amalgamating costs at the South mill for 1929, and Table 8 gives the details of costs for the stamps and rod mill of the South mill during the same period.

Tables 9 and 10 show summaries of costs of the cyanide sand plant No. 1 and of the slime plant, respectively, for 1929.

Table 11 gives the number and rates of pay of mill employees, not including assaying, refining, and departmental supervision, for the South mill, No. 1 cyanide sand plant and the cyanide slime plant.

Table 6. - Summaries of tramming and coarse crushing costs, 1929

Ore crushed, 1,437,935 tons.

| Tramming, dollars per ton | | Coarse crushing, dollars per ton | |
|---|---|---|---|
| Labor ...................... | 0.01282 | Labor ..................... | 0.01337 |
| Air ........................ | .00402 | Power ..................... | .00112 |
| Shop service ............... | .00458 | Repair labor .............. | .00777 |
| Supplies ................... | .00236 | Renewals, material ........ | .01597 |
| Track upkeep ............... | .00247 | Total ..................... | .03823 |
| Total operating ............ | .02625 | | |
| New tramway ................ | .00772 | | |
| Total, including new tramway | .03397 | | |

Table 7. - Summary of grinding and amalgamating costs at South mill, 1929, in dollars per ton of ore stamped.

Ore feed to stamps, 715,574 tons.
Ore feed to rod mills, 558,147 tons (factor 1.282)
Ore feed to tube mills, 86,000 tons (factor 8.32)

| | Plant labor and department overhead | Labor; service other departments | Castings and stamp parts | Iron and steel | Supplies | Power | Water | Total |
|---|---|---|---|---|---|---|---|---|
| Superintendence ..... | 0.01059 | | | | 0.00023 | | | 0.01082 |
| Miscellaneous (storehouse, yard, lighting, etc.). | .00815 | 0.00076 | | 0.00009 | .00086 | 0.00050 | | .01036 |
| Stamps ...... | .02110 | .00584 | 0.01863 | .00304 | .00292 | .01400 | 0.02347 | .08900 |
| Rod mills ... | .01699 | .00164 | .01321 | .03113 | .00147 | .01897 | | 1/ .08341 |
| Amalgamation. | .00525 | .00005 | | | .00848 | | | .01378 |
| Tube mills .. | .00629 | .00048 | .00113 | | .00257 | .00376 | | 2/ .01423 |
| Assaying .... | .00096 | .00324 | | | .00117 | | | .00537 |
| Refining .... | .00203 | .00543 | | | .00028 | | | .00774 |
| Total ....... | .07136 | .01744 | .03297 | .03426 | .01798 | .03723 | .02347 | .23471 |

1/ Cost per ton of feed to rod mills, $0.10693.
2/ Cost per ton of feed to tube mills, $0.11839.

Table 8. - Details of stamp and rod mill costs, South mill, 1929

| Stamps | | Rod mills | |
|---|---|---|---|
| | Dollars per ton fed to stamps | | Dollars per ton fed to rod mill |
| Care of motors ........... | 0.00114 | Care of motors ....... | 0.00060 |
| Power .................... | .01400 | Power ............... | .02432 |
| Operating labor .......... | .02110 | Operating labor ...... | .02178 |
| Shoes .................... | .00971 | Cones and classifiers. | .00177 |
| Dies and castings ........ | .00584 | Rods ................. | .03865 |
| Battery renewals ......... | .01031 | Liners ............... | .01439 |
| Miscellaneous supplies and upkeep ............. | .00343 | Miscellaneous ........ | .00266 |
| Water .................... | .02347 | | |
| Total .................... | .08900 | Total ................ | .10417 |

Table 9. - Summary of costs of Cyanide sand plant No. 1 for year 1929, dollars per ton of sand treated.

Sand treated, 636,654 tons.

| | Plant labor and department overhead | Labor; service other departments | Chemicals | Power | Supplies | Heating | Total |
|---|---|---|---|---|---|---|---|
| Superintendence.. | 0.008243 | | | | | | 0.008243 |
| Assaying ........ | .001734 | 0.005878 | | | 0.002125 | | .009737 |
| Refining ........ | .001170 | .003002 | | | .002239 | | .006411 |
| Transporting .... | .001242 | .000531 | | | .000629 | | .002402 |
| Neutralizing .... | .002743 | | [1]0.019033 | 0.000075 | | | .021851 |
| Classifying ..... | .008682 | .000301 | | .000338 | .000909 | | .010230 |
| Treatment ....... | .035125 | .002121 | [2] .029186 | .002815 | .001972 | | .071219 |
| Precipitating and pumping ....... | .006342 | .000175 | [3] .003710 | .000494 | .001854 | | .012575 |
| Miscellaneous ... | .002289 | .003789 | | .000263 | .003180 | 0.006722 | .016243 |
| Total .......... | 0.067570 | 0.015797 | 0.051929 | 0.003985 | 0.012908 | 0.006722 | 0.158911 |

[1] Lime.
[2] Cyanide.
[3] Zinc.

8563

Table 10. - Summary of costs of cyanide slime plant for year 1929; dollars per ton of slime treated

Slime treated, 584,482 tons

| | Plant labor and department overhead | Labor service other departments | Chemicals | Power | Supplies | Heating | New construction | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Plant additions | Bulkhead | |
| Superintendence.... | 0.00852 | | | | | | | | 0.00852 |
| Assaying .......... | .00231 | | | | 0.00194 | | | | .00425 |
| Refining .......... | .00216 | 0.00554 | | | .00413 | | | | .01183 |
| Thickening ........ | .00526 | .00033 | | | .00019 | | | | .00578 |
| Neutralizing ...... | .00817 | | 1/0.02896 | 0.00013 | | | | | .03726 |
| Treatment ......... | .04294 | .00742 | 2/ .04283<br>4/ .00574 | .00542 | 3/.01035<br>.00708 | | | | .12178 |
| Precipitating and pumping .......... | .00694 | .00038 | 5/ .01039 | .00052 | .00093 | | | | .01916 |
| Miscellaneous ..... | .00825 | .00158 | 6/ .00202 | .00038 | .00375 | 0.00411 | 0.00573 | 0.00231 | .02813 |
| Total ............. | .08455 | .01525 | .08994 | .00645 | .02837 | .00411 | .00573 | .00231 | .23671 |

1/ Lime.
2/ Cyanide.
3/ Press cloths.
4/ Hydrochloric acid.
5/ Zinc.
6/ Bleaching powder used experimentally for about two weeks.

Table 11. - Operating labor and wage rate

| Number of employees at | | | Wage rate, dollars |
|---|---|---|---|
| South Mill | No. 1 cyanide sand plant | Slime plant | |
| 1 | | | 7.25 |
| | 1 | 1 | 6.75 |
| 1 | | 1 | 5.75 |
| | 1 | | 5.50 |
| 3 | | | 5.25 |
| 1 | 3 | 4 | 5.00 |
| 2 | | | 4.75 |
| | 4 | 3 | 4.50 |
| 6 | 7 | 1 | 4.35 |
| 2 | 2 | | 4.25 |
| 3 | 4 | 9 | 4.15 |
| 3 | | 3 | 4.00 |
| 3 | 1 | 5 | 3.75 |
| 2 | | 1 | 3.50 |
| 27 | 23 | 28 | |

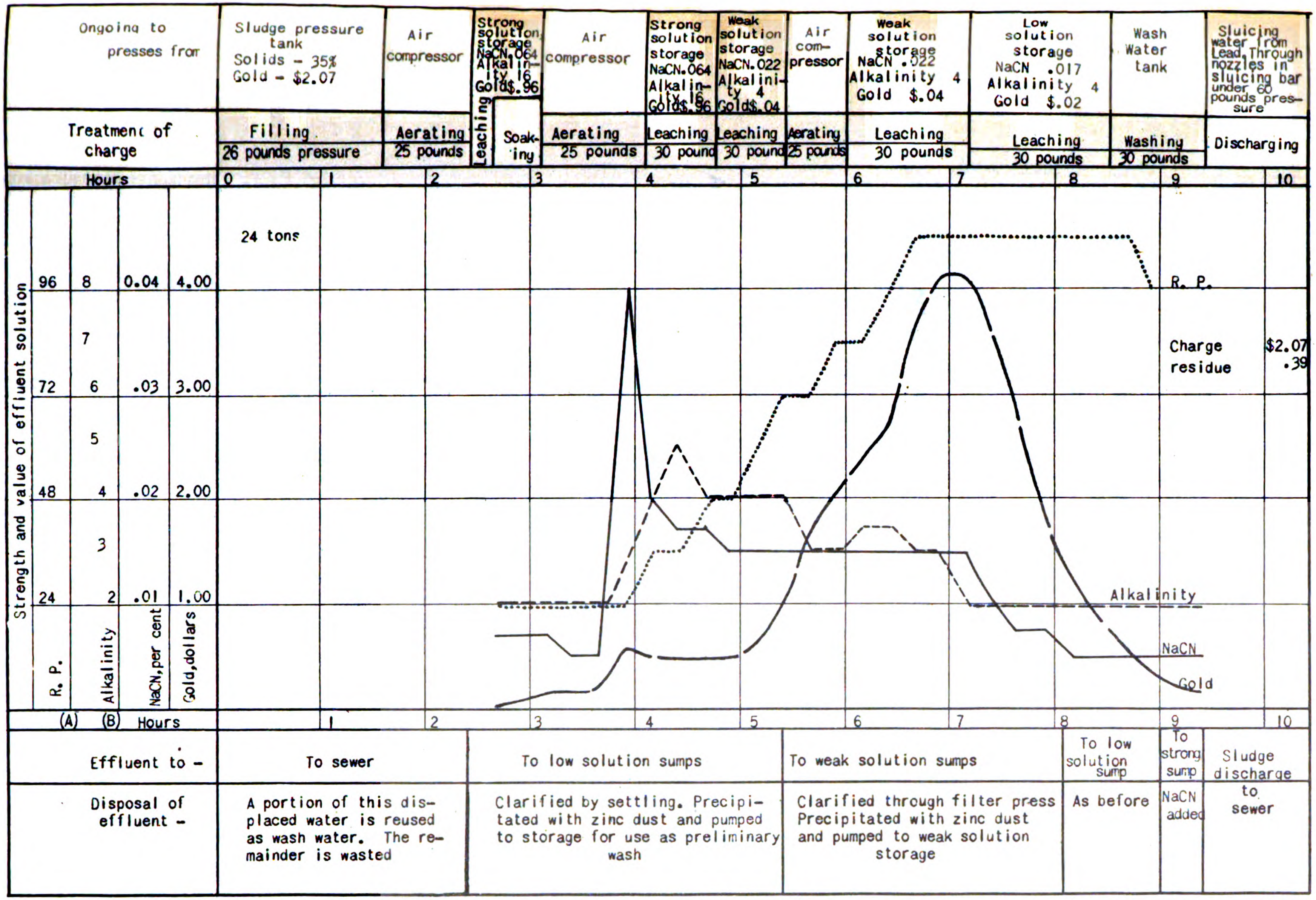

Figure 5.- Cycle of slime treatment, Homestake Mining Co., 1930: A, Reducing power is expressed as the number of cubic centimeters of N/10 potassium permanganate consumed by 100 c. c. of the solution tested; B, alkalinity is expressed as the number of cubic centimeters of N/10 acid required to neutralize 100 c. c. of the solution tested, one unit corresponding to 0.0028 per cent of CaO